Autonomous Vehicle Stereo Vision Sensor Package Design

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Industry & Impact

The NHTSA reported over **36,000 motor vehicle deaths** in 2019, and the IIHS estimates that **over 90% of motor vehicle crashes involve human error**. Autonomous vehicles may reduce these figures, but only with highly reliable sensing. Stereo vision cameras are one such form of sensing; Our task is to implement a stereo vision package for close-range sensing with a focus on camera alignment to improve safety and reduce costs.

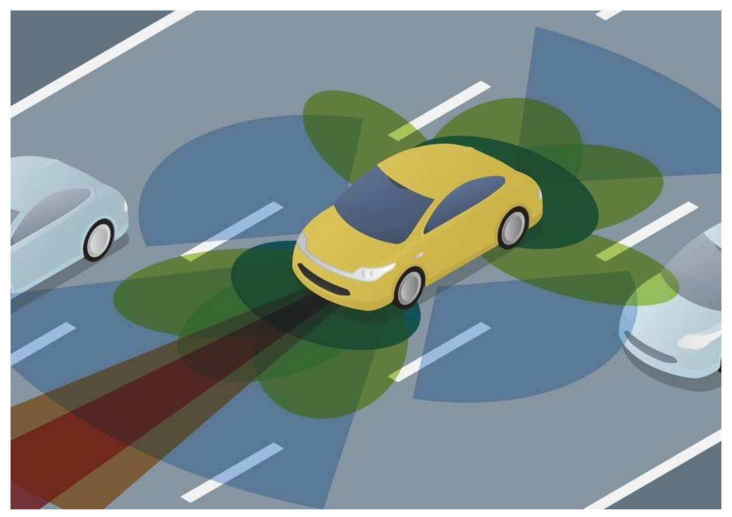


Image Courtesy: Car and Driver

System Requirements

Requirements:

- Maintain required sensor alignment and allowable sensor temperatures
- Survive 10G shock loading

Inputs:

- Solar load: Up to 750 W/m^2
- Ambient Temperature: -10 to 50°C
- Random Vibration PSD (shown in following section)

Degree of Freedom	Relative Requirement
X	1 [mm]
Y	1 [mm]
Z	1 [mm]
Pitch	1 [mrad]
Yaw	1 [mrad]
Roll	.5 [mrad]

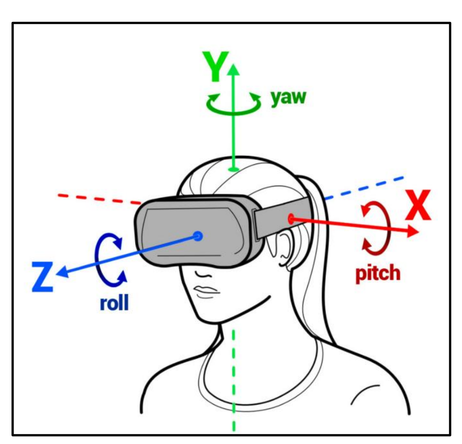
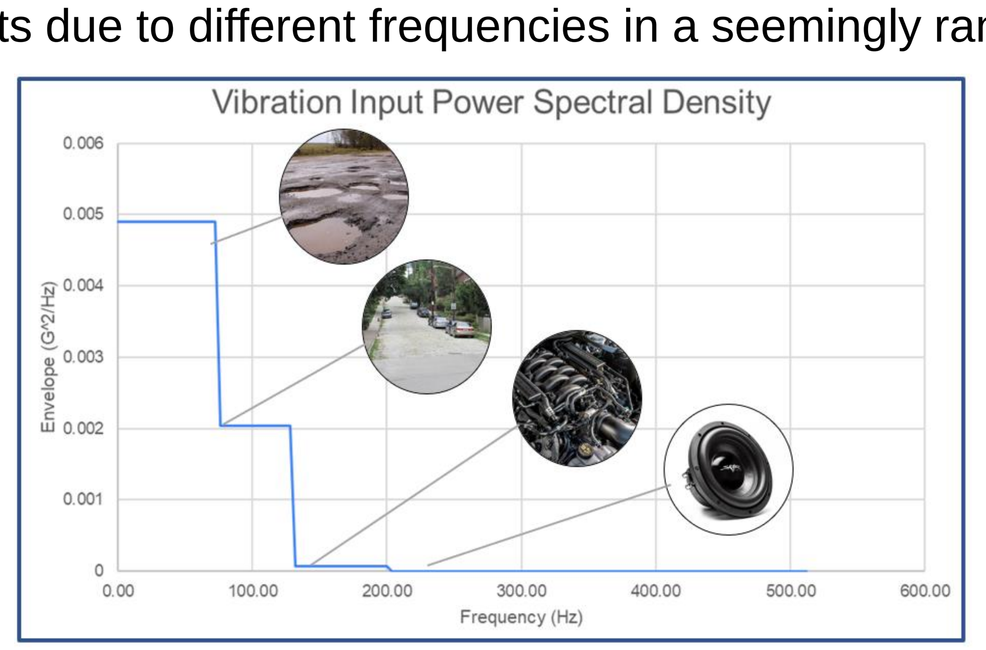


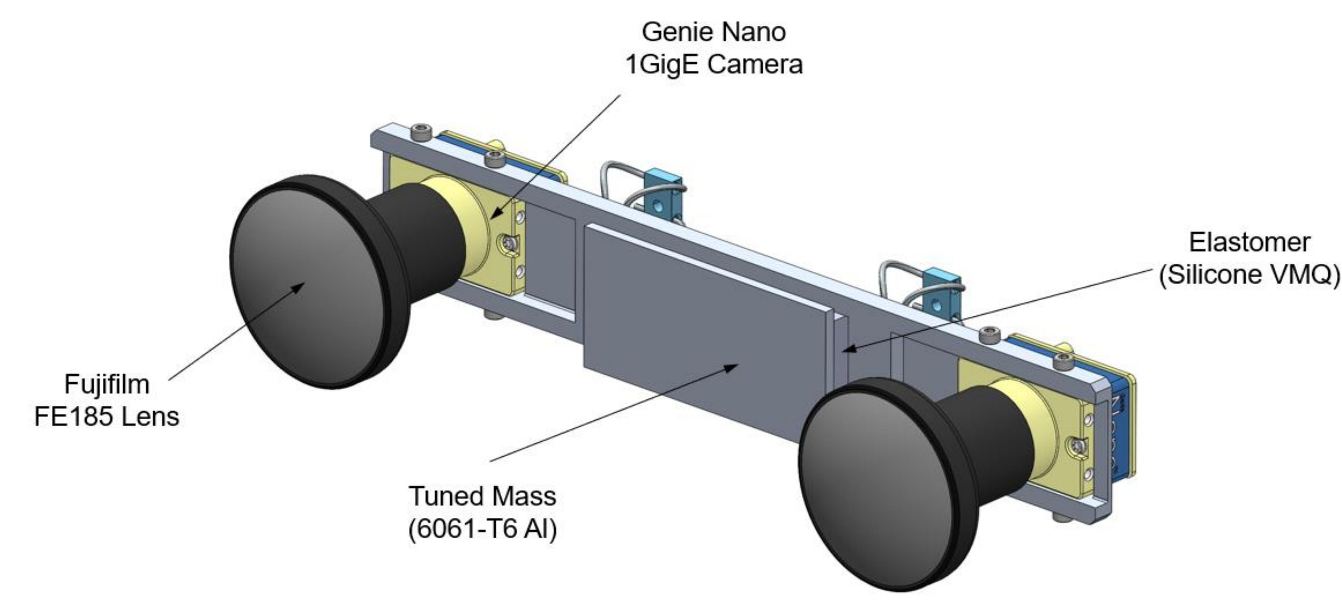
Image Courtesy: Awwwards

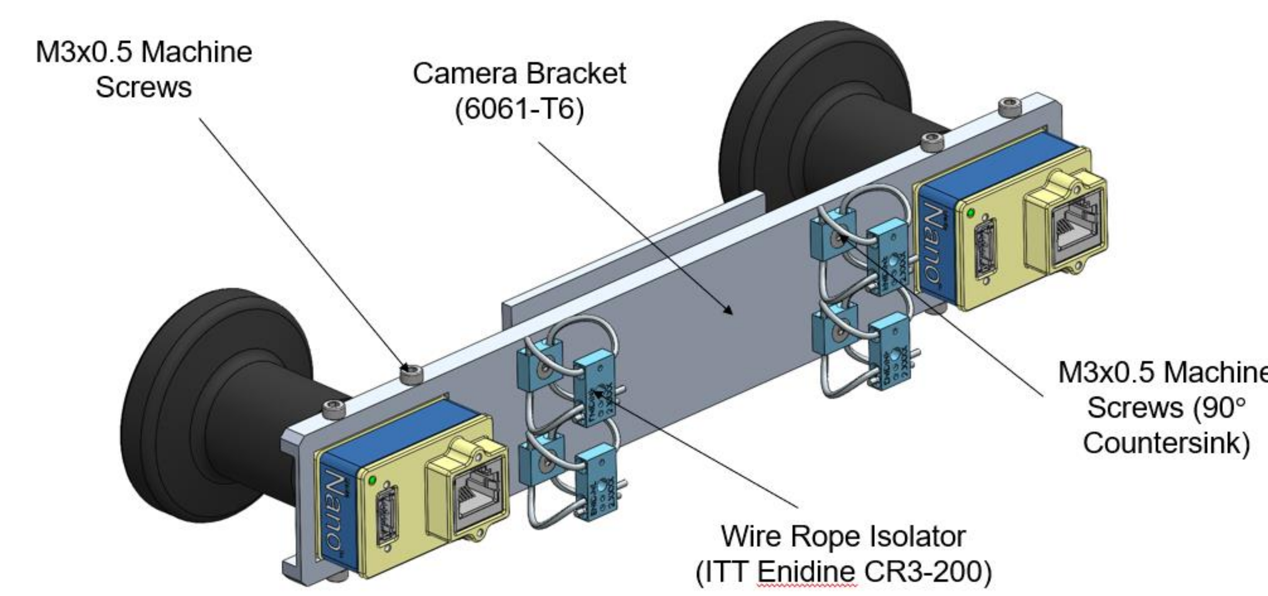
Random Vibration Input

Data from Argo AI was compiled into an input Power Spectral Density (PSD) function. This quantifies how much energy input into the sensor package exists due to different frequencies in a seemingly random signal.



Our Design





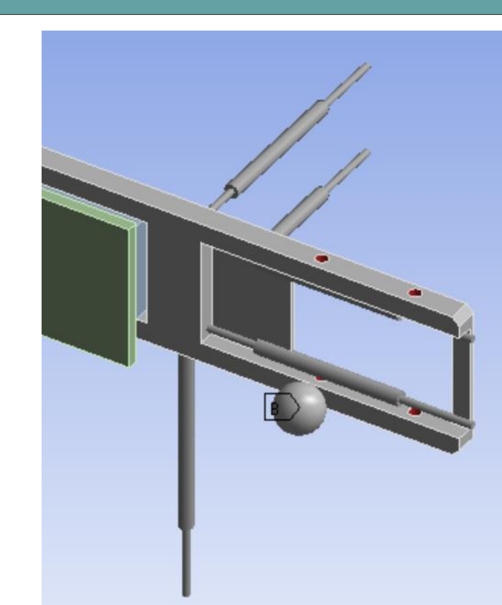
Analysis Methods

Static — Inputs: Fixtures, gravity & acceleration loads; Outputs: Maximum stresses and deflections

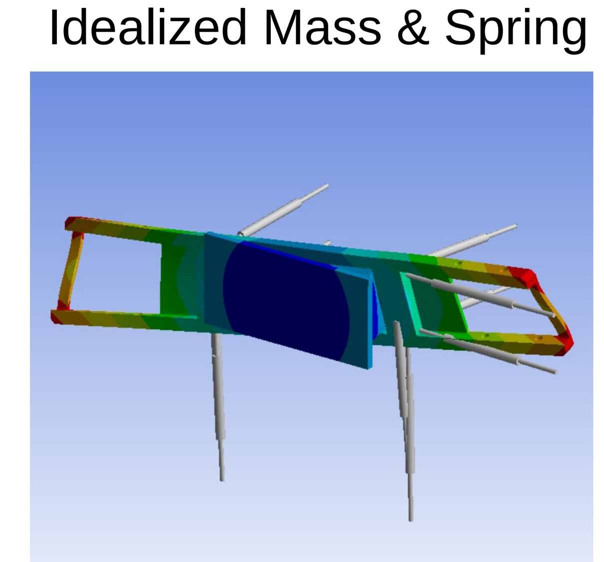
Modal — Inputs: Mass/stiffness properties, gravity pre-stress; Outputs: Resonant frequencies, mode shapes

Random Vibration — Inputs: modal analysis, acceleration PSD; Outputs: Response PSD, 3σ stresses and deflections

Thermal — Inputs: Heat flux, convection, and/or body temperatures; Outputs: Body temperatures, thermal stresses/deflections

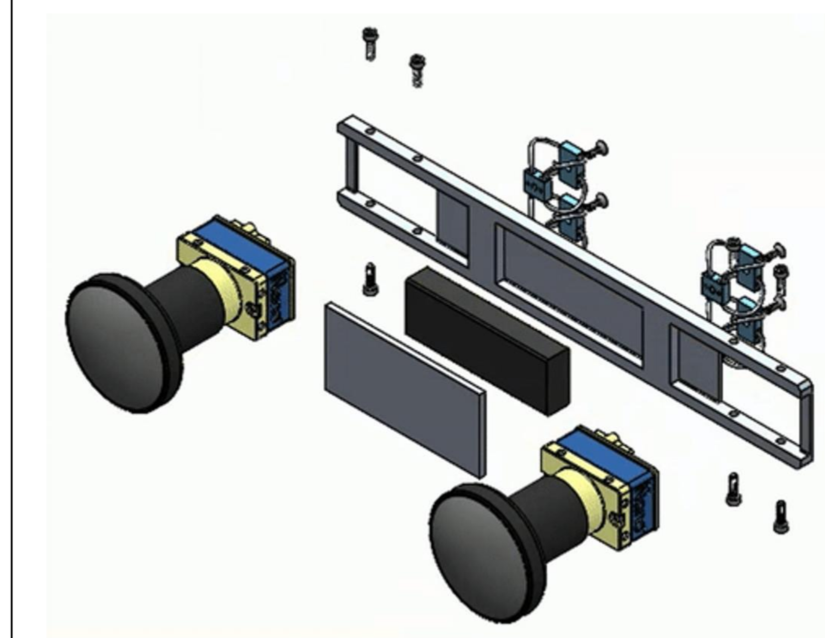


Idealized Mass & Spring



Sample Mode Shape Result

Manufacturability



1. Cut components from stock
2. Apply adhesive to rubber between bracket and plate
3. Bolt wire rope isolator to bracket
4. Fasten cameras/lenses to bracket
5. Bolt assembly to vehicle

*All bolted joints will have thread locker to prevent loosening from vibrational loading.

Results

Parameter	Unisolated Performance	Isolated Performance
Relative COM Displacement (X)	2.64 mm	0.90 mm
Relative COM Displacement (Y)	0.04 mm	0.24 mm
Relative COM Displacement (Z)	2.22 mm	0.34 mm
Relative Pitch	1.45 mrad	1.96 mrad
Relative Roll	0.30 mrad	0.13 mrad
Relative Yaw	53.2 mrad	8.61 mrad

Our proposed design led to **improvements in linear alignment, along with roll and yaw**. Additionally, the minimum **yield factor of safety increased from 1.1 to 3.2**. The bracket deflects up to 13.6 mm under shock loads; representing a required trade-off for enhanced isolation.

Future Considerations

Design:

- Optimize tuned mass damper geometry
- Electronics integration

Simulation:

- Camera & joint stiffness
- Non-linear rubber and wire rope isolator behavior

Manufacturability:

- In house capabilities/outsourcing
- Cost, time, material efficiency

Testing:

- Vibration table, vehicle mounting test drive
- Accelerometers and thermocouples

Acknowledgements

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